WASHINGTON STATE DEPARTMENT OF ECOLOGY

Periodic Dam Safety Inspection Report

Beitey Lake Dam

Stevens County, Washington

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Beitey Reservoir Dam

Stevens County, Washington

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Periodic Inspection Report

Water Resources Program
Report 01-11-009

The dam safety inspection of the Beitey Lake Dam, and the engineering analyses and technical material presented in this report were prepared under the supervision and direction of the undersigned professional engineers, in accordance with RCW 43.21A.064(2).

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1. Introduction

Under state law (RCW 43.21A.064(2)), the Department of Ecology has responsibility and authority to inspect the construction of all dams and other works related to the use of water, and to require necessary changes in construction or maintenance to reasonably secure safety to life and property. This report has been prepared in accordance with this statute.

The report presents the results of the first periodic inspection and safety evaluation of the Beitey Lake Dam by the Ecology Dam Safety Office (DSO). The report provides:

- Background information,
- A description of the project,
- Results of the October 17, 2000 inspection,
- Engineering evaluation and analyses of the design of the project,
- Required remedial actions based on the findings from the current inspection

2. Background Information on the Project

Beitey Lake is a trout rearing and recreational reservoir, located about 5 miles southeast of the city of Chewelah in Stevens County (Figures 1 and 2). The reservoir is impounded behind a 15-foot high earthfill dam, which is owned and operated by Mr. Jerry Beitey. The project lies on a small, unnamed ephemeral stream, which discharges through springs into Bulldog Creek, which in turn discharges into the Colville River. The reservoir is primarily filled by runoff from the surrounding 3.1 square mile watershed.

According to DSO files, the dam was designed and constructed by Mr. Beitey's father, Joseph G. Beitey. No reports or photographs are available describing the original construction of this dam. A sketch of the dam prepared by Joseph Beitey dated Jan 6 1931 shows a cross-section of the dam with a central concrete core wall, an upstream 'dirt' fill and a downstream rock fill. The concrete core wall was to be constructed '3 feet below creek bottom and reinforced with steel'. The sketch indicates that the dam was to be 10 feet high and provided with a 10 foot wide spillway on top. This differs from the actual dimensions of the structure, which has a height of 15 feet and was provided with a 6 foot wide spillway. The reservoir storage permit indicates that the dam impounds 100 acre-feet at the dam crest level.

On July 15, 1999, the DSO performed an inspection of the dam, in order to assess its condition and the downstream hazard potential in the event of a failure. This inspection revealed that at least one home had been built in the valley downstream from the dam since it was built. In addition, another dam had been built downstream from Beitey Lake in the 1970's. Thus, it was decided that the dam should receive a Class 1 inspection, to more thoroughly assess the hazard potential and to investigate what repairs might be needed to meet current dam safety standards. This report describes the Class 1 inspection and findings.

3. *Field Inspection of the Facility*

The field inspection of the Beitey Lake Dam was performed on October 17, 2000. The Dam Safety inspection team consisted of the following personnel:

Name	**Aspects Covered**
Douglas L. Johnson, P.E.	Coordinator, Hydrology/Hydraulics
Gustavo Ordonez, P.E.	Geotechnical
Guy Hoyle-Dodson, P.E.	Hydrology/Hydraulics

Mr. Jerry Beitey was present during the inspection and provided information on the history of the dam as well as current operation and maintenance procedures.

3.1 *Reservoir*

Beitey Lake has a surface area of 25 acres at the normal pool elevation of 2263.0 feet[a]. The reservoir impounds about 100 acre-feet at normal pool, and can impound approximately 220 acre-feet at the current dam crest elevation of 2266.9 feet. The reservoir is primarily filled by runoff from a small creek that drains the watershed, and by springs.

At the time of the inspection, the reservoir level was at elevation 2263.3 feet, which was 0.3 feet above the spillway stoplogs, and 3.6 feet below the dam crest level. The slopes on both sides of the reservoir were examined from the dam during the inspection. The slopes immediately surrounding the reservoir are fairly flat, so the chances of a landslide generating waves that could affect the dam appeared unlikely.

3.2 *Embankment, Abutments and Foundation*

Beitey Lake Dam is an earthfill embankment with a concrete core wall and downstream rock facing. The dam has a height of 15 feet, a crest width of 12 feet, and a crest length of 100 feet. A survey of the dam during our inspection revealed the crest elevation varies from 2266.9 feet near the spillway, to 2268 feet at the right abutment. (Figure 3). According to Mr. Beitey, the concrete core wall was reinforced with steel, and the top of the wall is about 2 feet below the dam crest level. The core wall was not founded in bedrock, but instead was founded in "hardpan" 3 feet below the streambed. The upstream

[a] All elevations in this report are based on an assumed local project datum of 2263.0 feet on top of the front stoplog in the spillway channel.

slope is inclined at about 2H:1V, while the downstream rock slope is nearly vertical. As far as Mr. Beitey knows, the dam was not provided with any drainage features to collect and control seepage.

We first inspected the visible portion of the upstream slope above the water line. No signs of cracking, instability or erosion were noted. Although no slope protection is provided, there was no evidence of wave erosion noted at the water line. A growth of grass at the water line appeared to provide adequate protection from erosion.

We next examined the dam crest, and discovered no cracks, sinkholes, erosion, or other signs of instability. Our survey of the dam crest did not show any obvious signs of settlement along the crest. According to Mr. Beitey, numerous loaded log trucks have crossed the dam crest over the years and the dam has held up well.

An examination of the downstream face of the dam revealed that there was no sign of displacement or movement of the rock facing. According to Mr. Beity, this facing was placed when the dam was constructed in the 1920's, and to his knowledge has never needed repair. No seepage was noted coming from the rock or downstream toe area. However, seepage was noted coming from the left abutment several feet downstream from the toe. The seepage was clear, and the total quantity was on the order of 2 gallons per minute. According to Mr. Beitey, this seepage has been present for as long as he can remember, and has not increased over the years.

3.3 Principal Spillway

The principal spillway for the Beitey Dam is a 6.3 foot wide, 29 foot long reinforced concrete chute the passes over the crest near the center of the dam. The spillway entrance is provided with a wood cover that prevents debris and ice from clogging the spillway entrance. The spillway chute is rectangular in section, with a variable depth, as the floor of the chute steps up twice from upstream to downstream. At the entrance, the chute floor is 13 feet below the dam crest level, then steps up 6 feet at the upstream edge of the wooden bridge that spans the spillway. Under the bridge the floor steps up another 3.3 feet. At this point the spillway floor is at elevation 2261.8 feet, and the side wall elevation is 2265.3 feet. Stoplogs are placed in two locations along the spillway chute, at the top of the first step, and at the downstream end of the chute. The crest elevation of both sets of stoplogs is 2263.0 feet. The chute is cantilevered a few inches over the downstream rock facing to project flow beyond the toe of the dam. A 6-foot wide prefabricated corrugated metal trough is provided as an energy dissipator where the spillway flows drop onto the outlet channel.

Our inspection of the spillway structure revealed it to be in surprisingly good condition, given its age and lack of formal engineering design. The concrete was in excellent condition, and no signs of cracking, spalling or other deficiencies were found. According to Mr. Beitey, the spillway has performed well over the years with few operational problems. The only significant problem noted with the spillway was the lack of an adequate energy dissipator and erosion protection on the downstream face and toe area.

Erosion protection on the downstream face consisted of corrugated metal sheets strapped to the rock facing. Under large spillway flows, these sheets would not be sturdy enough to protect the facing. The trough used as an energy dissipator may be adequate for low flows, but would be overwhelmed during floods. Failure of either or both of these elements during a flood could result in severe erosion at the toe and threaten the stability of the dam. Thus, the energy dissipator and slope protection need to be significantly improved.

3.4 Outlet Works

There are no low-level outlet works at this dam.

4. Evaluation and Analyses

4.1 Downstream Hazard Classification

It is common practice to use a classification system to describe the general level of development downstream from a dam, which could be affected by a flood should the dam fail. This classification is used for selecting minimum design levels for the various elements of the facility, such as the flood used to design or analyze the spillway(s). Table 1 below lists the classification system used by the Dam Safety Office.

Table 1. Downstream Hazard Classification

Downstream Hazard Potential	Downstream Hazard Classification	Column 1A Population at Risk	Column 1B Economic Loss Generic Descriptions	Column 1C Environmental Damages
Low	3	0	Minimal. No inhabited structures. Limited agriculture development.	No deleterious materials in water
Significant	2	1 to 6	Appreciable. 1 or 2 inhabited structures. Notable agriculture or work sites. Secondary highway and/or rail lines.	Limited water quality degradation from reservoir contents.
High	1C	7 to 30	Major. 3 to 10 inhabited structures. Low density suburban area with some industry and work sites. Primary highways and rail lines.	
High	1B	31-300	Extreme. 11 to 100 inhabited structures. Medium density suburban or urban area with associated industry, property and transportation features.	Severe water quality degradation potential from reservoir contents and long-term effects on life.
High	1A	More than 300	Extreme. More than 100 inhabited structures. Highly developed densely populated suburban or urban area.	

Prior to the 2000 inspection, the setting downstream from the Beitey Lake Dam was classified as having a Hazard Class of 2, if a dam failure should occur. As part of the inspection, the downstream hazard potential was reassessed. Downstream from Beitey Lake Dam, the creek flow through a valley for 1.7 miles until it reaches Serenity Lake (Jumpoff Jim Reservoir), which is impounded behind a 10 foot high dam. There is one home located along the creek in this section. Downstream from Serenity Lake, the creek flows down to the 20-foot high roadfill for Highway 395. One home is located along the creek in this reach. At Highway 395, the only outlet under the roadfill to drain the upper basin is a 36-inch culvert. Due to the limited capacity of this culvert, large floods would back up behind the roadfill. Downstream from Highway 395, the creek flows into the headwaters of Bulldog Creek. Ten more homes are located between Bulldog Creek and the Colville River that could be affected should the Highway 395 roadfill fail.

4.1.2 Dam Break Analysis

Based on this complex setting of the downstream valley, two hydraulic computer programs were used to model the dam break flood in the downstream floodplain: the U.S. Army Corps of Engineers HEC-1 and HEC-RAS computer models. First, the failure of Beitey Lake Dam was simulated using the US Army Corps of Engineers HEC-1 computer model. Input parameters for computing the dam breach were based on procedures contained in Technical Note 1 – Dam Safety Guidelines[1]. The breach parameters for Beitey Lake included a base width of 15 feet, side slopes of 2H:1V and a time to failure of 30 minutes. The dam break discharge at Beitey Dam was computed for a failure during a 500-year flood of 90 cubic feet per second (cfs) on the watershed, with the spillway assumed to be partially blocked by debris prior to failure. (This flood was selected because it is the minimum design flood for any dam in Washington State, and the lake would be filled to the dam crest level prior to failure.) Using these parameters, the dam break peak discharge was computed to be 4390 cfs, which is over 48 times larger than the 500-year flood. The total volume released by the dam break was over 250 acre-feet of water.

The dam break hydrograph from this run was then input into the HEC-RAS unsteady flow program to model the stream reach between Beitey Lake and Serenity Lake. This model was used because of the need to obtain more precise flood depths at the location of the home 0.9 miles downstream from the dam. This model run indicated that the home would be inundated by about 3 feet of water with a velocity of 4 feet per second and a discharge of 3900 cfs. Such an inundation depth and velocity could prove deadly to residents of this home.

Downstream from this home, the hydrograph from this flood was then input back into the HEC-1 computer model, and the flood was routed through Serenity Lake and Dam. The peak discharge from the flood had attenuated down to 3570 cfs at this point. Because of the limited capacity of the Serenity Lake Dam spillway, however, the Beitey dam break flood would still result in a subsequent failure of this dam. The peak discharge at Serenity Lake Dam was 4230 cfs, and perhaps more importantly, the total volume of the flood was now over 450 acre-feet.

The combined dam break flood was then routed downstream to the US Highway 395 roadfill using the Muskingum Routing routine in the HEC-1 model. (*More detailed flood routing was not considered necessary here, as the only home in this reach would not be inundated initially by the dam break flood, but would be flooded by backwater behind the Highway 395 roadfill.*) The dam break flood was then routed through the roadfill, modeling it as a dam and reservoir. The elevation-storage capacity curve was developed using USGS topographic maps and DSO survey data. The maximum storage capacity behind the roadfill before it begins to overtop the right abutment (at Elev. 2059.0 feet) was estimated to be 350 acre-feet. Since the 500-year flood was already occurring, the limited capacity of the culvert resulted in the roadfill already being surcharged to within 3 feet of the abutment prior to arrival of the dam break flood. The dam break flood would greatly exceed the remaining storage capacity and would overtop the roadfill by 2.8 feet. It is likely that the Highway 395 roadfill would fail under this loading, either by overtopping or piping or both. If the roadfill fails, the HEC-1 model estimated the peak discharge at nearly 8,000 cfs. The detailed flood routing was not carried beyond the Highway 395 roadfill. Clearly, by inspection, a flood of this magnitude would overwhelm Bulldog Creek and destroy the 10 homes located there.

Based on these findings, a total of 13 homes are potentially at risk from a failure of Beitey Lake Dam. In addition, the dam break flood would wash out a major state highway, and cause another two small dams to fail. Therefore, the hazard classification for the Beitey Lake Dam should be upgraded to **Hazard Class 1B, *High*** Downstream Hazard.

4.2 Hydrology and Spillway Adequacy

As part of this inspection, a hydrologic analysis was performed to assess the adequacy of the project's spillway. A summary of that analysis is provided in the following sections.

4.2.1 Hydrologic Characteristics of the Watershed

Based on 65 years of record at the Deer Park Weather Station, and on isopluvial maps of Washington State prepared by the US Weather Bureau, the mean annual precipitation for the Beitey Lake basin is about 22 inches. The season distribution is such that about 68% of the annual precipitation falls between October and March. Much of this precipitation falls as snow, and results in a winter snowpack that typically reaches a maximum in January or February. Historically, the greatest 24-hour precipitation amounts observed in the region around Beitey Lake have generally occurred between November and March. The greatest 24-hour storm measured at a nearby weather station was 2.35 inches at Chewelah in May 1998. Other large general storm events in the area have included 1.96 inches in 24 hours and 3.1 inches in 72 hours at Chewelah in November 1973, and 1.97 inches in 24 hours at Deer Park in December 1966.

Generally, three types of flood events can occur in Eastern Washington. The first type is a combined rain and snowmelt event, occurring in winter or early spring. The second type is a snowmelt flood, which occurs every spring in response to seasonal warming. The third type is a thunderstorm flood event, which occurs in response to intense rainfall during spring or summer thunderstorms. Runoff in the area around Beitey Lake is relatively small, due to the semi-arid climate and high infiltration rates of the soils. This is evidenced by the small size of the stream channel in relation to the basin size, and the fact that the stream "sinks" and runs underground downstream from Highway 395. However, if a storm is sufficiently large, the precipitation intensity can exceed the infiltration capacity of the soils, resulting in significant overland flow or "flash floods". These floods are quite rare, as they occur only once or twice in a lifetime, but when they do occur, their results can be devastating.

4.2.2 Selection of Design Storm

The first step in the hydrologic analysis was to select a design storm appropriate for the level and type of development downstream from the dam. The DSO uses design storm selection criteria[2] that have an eight-step format. Design storms range from a minimum of a 500-year storm (Step 1) to the Probable Maximum Precipitation (Step 8). Based on the extreme consequences of a dam failure including loss of lives described in Section 4.1.1, the Dam Safety Guidelines require that the dam be capable of passing a Design Step 4 event. A Step 4 storm has about a 1% chance of being exceeded in a 100-year period. Therefore, a Design Step 4 storm was used to determine the IDF.

The type of storm selected for analyzing the Beitey Reservoir Dam and spillway was a long duration, rain on snow event, as discussed in Section 4.2.1. This type of storm produces a flood having a moderately large flood peak and a large runoff volume. This storm is critical for this basin, because the flood storage available in the Beitey Reservoir is fairly large in relation to the size of the watershed. (A Step-4 thunderstorm event was also considered, but was not used as it produced a smaller runoff volume and did not raise the reservoir level quite as high as for the general storm.) The Step 4 design general storm has a 6 hour depth of 2.2 inches, a 24 hour depth of 5.3 inches and a 72-hour depth of 7.25 inches. This storm is about twice as large as the 100-year event. Estimates of the precipitation amounts were made using data contained in NOAA Atlas 2[3] and analyses of extreme storms in the region[4]. The temporal distribution of the design storm was developed based on the Washington Dam Safety Guidelines, Technical Note 3[5], using the 50% exceedance hyetograph.

4.2.3 Rainfall-Runoff Model

The hydrologic analysis performed by the DSO utilized the U.S. Army Corps of Engineers HEC-1 program, to analyze the runoff characteristics of the basin for the design storm. HEC-1 is a single event model capable of simulating direct runoff from the land surface, channel routing in the creeks, as well as reservoir elevations and discharges. Inputs to the HEC-1 model include precipitation, land cover, soil types, and hydraulic characteristics of the reservoir. Input data necessary for computing the floods produced by rainfall events is summarized below.

A major limitation with HEC-1 is that it cannot simulate subsurface discharge to creeks or reservoirs. All precipitation that infiltrates is assumed lost from the system. This limitation is a problem for basins such as Beitey Lake, because the infiltration capacity of the soil is quite high in relation to the rainfall intensities. A modeling scheme was developed for use with the 72-hour storm that approximates a subsurface flow component for the infiltrated precipitation. This scheme is detailed later in this report.

Drainage Basin – The drainage basin above Beitey Lake Dam has a total area of 3.1 square miles (Figure 4). The basin is largely forested with Ponderosa pine. Basin elevations range from 2260 feet at the dam to over 3200 feet at the southern boundary. For purposes of runoff modeling, the watershed was divided into two subbasins, the watershed surrounding the lake and the lake itself.

Soils and Infiltration - Based on USDA Soil Conservation Service soils mapping[6] of the area, the soils in the basin consist predominately of loams and silt loams from the Aits, Bonner, Huckleberry, and Raisio soil groups. The SCS lists the permeability of these soils to be 0.6 to 2.0 inches/hour, and classifies them in hydrologic soil groups B and C. Bedrock and glacial till underlies these soils at depths ranging from 30 to 60 inches. Based on the preceding information and on calibration runs described below, a uniform infiltration rate of 0.50 in/hr was used for the upper soil layer, and a deep percolation rate of 0.07 in/hr was used for the bedrock/till layer, with an initial loss of 1.0 inches.

The high surface permeability of the soils indicates that very little, if any, surface runoff occurs from typical storm events, and shallow groundwater flow is likely the dominant runoff mechanism in the basin.

Unit Hydrographs - The Gamma Distribution[7] was used as the unit hydrograph for surface runoff. The flow peak and travel time were computed using methods derived by the USBR in Design of Small Dams[8] for the Coast & Cascade Ranges of Washington. The computed lag time for the basin was 70 minutes, and a 10-minute unit hydrograph was selected.

The Gamma Distribution was used for the subsurface hydrograph because it provides the flexibility needed to set the volume beneath the hydrograph peak as well as the time of the peak. This flexibility is necessary when simulating a subsurface response because subsurface hydrographs are attenuated and have a much longer duration compared to surface hydrographs. The lag times for the subsurface runoff component was set at 8 hours, based on computed time lags for basins in the Puget Sound lowlands[9] and on calibration runs. The unit hydrograph peak flow rate is defined by Equation 1, where k is the percent of the hydrograph discharge that occurs beneath the peak. For a subsurface response, a k value of 7.5 percent was used. This produces a unit hydrograph that has a ratio of recession to rise time of about three to one.

$$Q_p = \frac{1936kAR}{\mathrm{P_r}} \tag{1}$$

Where: **k** is the percent of hydrograph discharge, which occurs during the time increment $P_r/5$ of the flood peak.
P_r is the period of rise of the hydrograph (hours).
A is the watershed area, (square miles).
R is the volume of runoff, (inches).

Snowpack Data – Snow is common in the basin and the snowpack typically reaches a maximum in January or February. Based on information in the hydrologic analysis for nearby Power Lake Dam[10], a 5-year snow water content of 5.0 inches was assumed to be present during the design storm event. Temperature data at the Chewelah station from the January 14-16, 1974 storm and flood were used as input to model the snowmelt. The degree-day method of snowmelt was used, with a melt coefficient of 0.11. This resulted in a total snowmelt during the design storm of 3.6 inches.

4.2.4 Model Calibration

The infiltration rates were calibrated based on comparison of the HEC-1 model flow data to regional flood frequency estimates for the 25 and 100-year floods. These flood estimates were determined from the regression equations contained in USGS Water Resource Investigation Report 97-4277 *Magnitude and Frequency of Floods in Washington*[11]. Based on this report, the 25-year flood had a peak discharge of 44 cubic feet per second, and the 100-year flood had a peak discharge of 64 cfs. The watershed was then modeled using HEC-1 with the 25 year and 100-year, 72-hour general storm event with no snowmelt. Only the interflow component was modeled, as the precipitation intensities of these storms were less than the infiltration capacity of the upper soil layer. The infiltration parameters were then adjusted until the peak flow from both events approached the USGS estimate. The final parameters selected are described in the previous section.

4.2.5 Inflow Design Flood

The above parameters were used in the HEC-1 model to determine the Inflow Design Flood (IDF). The total inflow hydrograph (surface, interflow, and rainfall on the lake) is shown in Figure 5. The computed Step 4 IDF had a peak inflow of about 330 cubic feet per second (cfs), with a total runoff volume of 940 acre-feet (5.7 inches) on the watershed.

4.2.6 Flood Routing through Reservoir and Spillway

To determine the response of the reservoir to floods, flood routing procedures were used in the HEC-1 model to determine the maximum lake elevation and spillway discharge. Reservoir routing of the IDF was performed using the as-built principal spillway configuration. Spillway discharge capacity information is needed as part of the flood routing analysis for the facility. An elevation-discharge curve was computed for the existing spillway and the maximum discharge capacity was 155 cfs with the reservoir at top of dam level.

The initial reservoir elevation was set at 2263 feet, which is at the principal spillway stoplog elevation. This reservoir level is considered the normal maximum operating level. The flood routing revealed that the IDF exceeded the capacity of the existing spillway, and would overtop the dam by one foot for several hours. Such a depth of overtopping would likely result in an erosive failure of the downstream rock fill, removing support for the concrete core wall. This in turn would probably result in collapse of the core wall and failure of the dam. Based on the foregoing, with the present dam and spillway configuration, Beitey Lake Dam cannot safely accommodate the IDF. In fact, the analysis showed that the facility can presently only handle about 50% of the design flood.

4.2.7 *Spillway Repair Options*

Since the Inflow Design Flood discussed in the previous section overtops the dam, it is clear that modifications will be needed to increase the spillway capacity to pass the flood. Fortunately, the spillway deficiency at Beitey Reservoir Dam is relatively easy to rectify. Three options are proposed to increase the spillway and storage capacity to allow the dam to handle the design flood. These options are detailed as follows.

Option 1: 10 foot wide emergency spillway – This option would involve excavating a 10-foot wide emergency spillway around the left (south) abutment of the dam with a floor elevation of 2265 feet, and adding one foot of fill to the dam crest to raise the elevation to 2268.0 feet. Figure 6 provides a conceptual drawing of this repair scheme. With these modifications, the dam can handle the IDF with 0.6 feet of freeboard below the crest elevation. The advantage of this scheme is that it would be relatively easy and inexpensive to construct. The disadvantage is that it would require extensive regrading of the road on the left abutment to maintain access across the dam for logging trucks. Also, the concrete sidewalls of the spillway chute would have to be raised one foot.

Option 2: Install Two 36-inch Pipes on Left Abutment – This option would involve installing twin 36-inch diameter Corrugated Metal Pipes through the left abutment of the dam, with the invert elevation of the pipes at 2263.5 feet (Figure 7). The pipes would discharge into a channel on the downstream left abutment that would direct spillway flows away from the toe of the dam. Under this repair scheme, the dam could pass the flood with 0.5 feet of freeboard below the crest. The advantage of this scheme is that the dam crest and existing spillway walls would not have to be raised, and the road over the dam would not require regrading. The disadvantage would be the cost of purchasing and installing the conduits.

Option 3: Make Dam Overtoppable – This option would involve providing a concrete surfacing on the dam crest to enable it to withstand overtopping flows (Figure 8). First, up to 12 inches of fill would be removed from the dam crest to lower the crest elevation to 2266.0 feet. Next, a trench would be excavated to expose the top of the concrete core wall. This would allow dowels to be drilled into the top of the core wall to tie the overtopping protection to the core. Then a 6-inch thick concrete slab would be constructed across the dam crest and onto the core wall. Reinforcing steel would be required sufficient to support the weight of truck traffic. Formwork would be needed to extend the slab several inches beyond the downstream rock facing. Finally, curbing (either wood or concrete) would be needed along the downstream edge of the slab to direct the flows over the center of the dam. Figure 8 provides a conceptual drawing of this repair scheme. The advantage of this scheme is that all work would take place on the dam crest, and no work would be required in the abutment area. The disadvantage would be the higher complexity and cost of construction.

4.3 Embankment Stability

As part of the inspection, the stability of the critical embankment section of Beitey Dam was evaluated.

Static Stability - A static stability analysis was not performed for the dam cross-section. First, the dam is a complex composite structure, with an upstream earthfill section, central concrete core wall, and downstream rock facing. As a practical matter, such an analysis would require representative soil data on the embankment, core wall and foundation that presently, to our knowledge, do not exist. Second, and more importantly, the performance of the dam for its 70-year lifespan has been good. The dam exhibits no signs of instability or seepage, and the concrete core wall would tend to prevent a slope failure from breaching the embankment. Therefore, based on the forgoing, the static stability of the embankment is judged to be satisfactory.

Pseudostatic Stability - Based on the USGS seismic hazard maps[12], and using a similar hazard level as for the hydrologic analysis (i.e., a 2% probability of exceedance in 50 years), a peak horizontal acceleration of 0.14 g is recommended for the region where the dam is located. Current practice for the pseudostatic analysis would recommend the use of a coefficient of 0.07 g, which corresponds to half of the peak acceleration. It is our opinion that for this level of seismic loading, the dam may not be significantly affected. There may be some movement of the rock facing and minor cracking of the soils, mainly on the embankment sections adjacent to the concrete wall. However, it is not expected that significant deformations of the embankment soils would occur that could cause a failure of the concrete core wall leading to a sudden release of the reservoir contents.

Thus, based on the forgoing qualitative evaluations, the stability of the embankment is judged to be adequate.

4.4 Operation & Maintenance

The owner does not have a written Operation and Maintenance (O&M) Plan for Beitey Lake Dam. Operation of the dam involves adjusting the stoplogs to regulate lake levels and outflow to meet the needs of fish rearing in the lake. Maintenance is performed on an as-needed basis, and primarily consists of removing ice and debris from the spillway entrance, maintaining the metal sheeting to prevent spillway flows from impinging on the downstream face, and repairing animal burrows. Mr. Beitey lives adjacent to the dam, and frequently inspects the facility for obvious deficiencies.

The lack of formal O&M procedures at the dam is of some concern. Furthermore, the Dam Safety Regulations require that an O&M Manual be prepared for a facility within 180 days following inspection by the Department of Ecology. Thus, a formal O&M Plan must be prepared for the dam, containing information on the regular operation, maintenance, inspection, and monitoring of the dams. Additional information on this requirement is provided in Ecology Publication No. 92-21, *Guidelines for Developing Dam Operation and Maintenance Manuals*.

3.5 Emergency Preparedness

At present, emergency preparedness at the Beitey Lake Dam is unsatisfactory. No Emergency Action Plan has been prepared for this facility, as was required following the 1999 DSO inspection.

The Dam Safety Office requires owners to develop and maintain an Emergency Action Plan for all dams located above populated areas. This plan must contain procedures for notifying downstream residents of an impending dam failure, as well as the specific circumstances under which a warning is issued, and actions to take in emergency situations to help prevent, or minimize the impacts of, a dam failure.

Considering the foregoing, an EAP needs to be written in accordance with the DSO guidelines and this report. Responsible parties need to be familiar with the plan, and aware of their responsibilities in an emergency. Information on EAP requirements is provided in Ecology Publication No. 92-22, *Guidelines for Developing Emergency Action Plans*.

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5. Conclusions and Required Remedial Actions

Based on our inspection, the Beitey Reservoir Dam is a fairly well constructed and maintained structure. However, the spillway capacity at the dam is inadequate, given the increased downstream hazard potential. This deficiency, along with the other needed corrective actions, are discussed as follows.

5.1 Increase Spillway Capacity at the Dam

As discussed previously in this report, Beitey Lake Dam does not have adequate spillway capacity for handling the Step 4 Inflow Design Flood event. In fact, the existing dam and spillway can only handle about 50 percent of the design flood. Thus, modifications are needed to increase the spillway capacity. Three possible options for the capacity increase were detailed in Section 4.2 and are summarized here:

1. **Construct 10 foot wide emergency spillway** – This option would involve excavating a 10-foot wide emergency spillway around the left (south) abutment of the dam, and adding one foot of fill to the dam crest to raise the elevation to 2268.0 feet. Figure 6 provides a conceptual drawing of this repair scheme.
2. **Install Two 36-inch Pipes on Left Abutment** – This option would involve installing twin 36-inch diameter Corrugated Metal Pipes through the left abutment of the dam, with the invert elevation of the pipes at 2263.5 feet. The pipes would discharge into a channel on the downstream abutment that would direct spillway flows away from the toe of the dam. Figure 7 provides a conceptual drawing of this repair scheme.
3. **Make Dam Overtoppable** – This option would involve providing a concrete surfacing on the dam crest to enable it to withstand overtopping flows. First, up to 12 inches of fill would be removed from the dam crest to lower the crest elevation to 2266.0 feet. Next, a trench would be excavated to expose the top of the concrete core wall. This would allow dowels to be drilled into the top of the core wall to tie the overtopping protection to the core. Then a 6-inch thick concrete slab would be constructed across the dam crest and onto the core wall. Reinforcing steel would be required sufficient to support the weight of truck traffic. Formwork would be needed to extend the slab several inches beyond the downstream rock facing. Finally, curbing (either wood or concrete) would be needed along the downstream edge of the slab to direct the flows over the center of the dam. Figure 8 provides a conceptual drawing of this repair scheme.

Whichever of the options is chosen, detailed plans for the selected repair scheme will have to be prepared by a professional engineer and approved by the DSO prior to construction.

5.2 Improve Erosion Protection Below Existing Spillway

Presently, discharge from the spillway chute impinges on the downstream face of the dam. Mr. Beitey has placed corrugated metal sheeting over the rock facing in an effort to prevent spillway flows from dislodging the rock. However, the sheeting is flimsy and poorly anchored. Under large spillway flows, the sheeting could break loose and the rock could be dislodged, removing support for the core wall and threatening the stability of the dam. Thus, the sheeting should be replaced with some sort of protection that is sturdier and well-anchored to the slope. One option would be to use heavier steel sheeting supported on wood framing.

5.3 Improve Energy Dissipator at Downstream Toe

Currently, a prefabricated corrugated metal watering trough provides energy dissipation of spillway flows dropping from the chute to the downstream toe. This arrangement works fairly well for low flows, but would be overwhelmed by major flood flows, leading to erosion of the toe and undermining of the rock facing. A more substantial energy dissipator is needed to adequately handle flood discharge from the spillway. A simple solution to this problem would be to create a stilling pool in the stream channel at the downstream toe. This could be accomplished by excavating a basin 3 feet to 4 feet deep at the location of the metal trough. The basin should be about 7 feet wide and extend at least 10 feet downstream from the current location of the trough. The basin would be lined with riprap for erosion protection, and a concrete cutoff wall should be placed at the upstream end to prevent undermining of the downstream toe. Figure 9 shows a conceptual design for this stilling pool.

5.4 Operation and Maintenance Plan

An Operation and Maintenance Plan must be prepared for Beitey Dam. As a minimum, the O&M Plan should include:

- A listing of procedures involved in operation of the dam, and the person(s) responsible for performing them.
- Procedures for the owner to conduct monthly and annual inspections of the dams.
- Routine maintenance activities that must be performed regularly, such as grass and brush trimming, debris removal from the spillway, and repair of animal burrows.
- Routine monitoring and recording of seepage flows.

Additional information to assist in developing the O&M Plan is contained in Ecology Publication No. 92-21, *Guidelines for Developing Dam Operation and Maintenance Manuals.* The Simplified O&M Plan Form can be used in lieu of completing a lengthy manual from scratch. This plan must be submitted to the DSO within 180 days following issuance of this report, as required in WAC 173-175-510.

5.6 Emergency Action Plan

An Emergency Action Plan needs to be written for Beitey Dam to meet current DSO requirements. The EAP should include the following:

- Notification procedures (preferably in the form of a flow chart) and responsibilities for notifying downstream residents in case of an impending dam failure.

- A notification list that includes the names and telephone numbers of local emergency officials and appropriate government agencies (including the Dam Safety Office).

- A clear description of situations where the need for warning should be issued. Such situations would include excessive, cloudy or muddy seepage; embankment slumps, or depressions forming on the slopes.

- Specific instructions for the owner to be followed at the dam site in response to emergencies such as heavy rains, equipment failures, or other unusual events where the situation is evolving slow enough that immediate remedial action can be effective to prevent failure.

- Procedures to follow for emergency situations that probably would not lead to dam failure, but still could represent a hazard for downstream residents.

- Dam breach inundation maps (see Figure 5).

Detailed information on preparing an Emergency Action Plan is contained in Ecology Publication 92-22, *Guidelines for Developing Dam Emergency Action Plans*. Again, this plan must be submitted to the DSO within 180 days of issuance of this report.

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Appendix A - Figures

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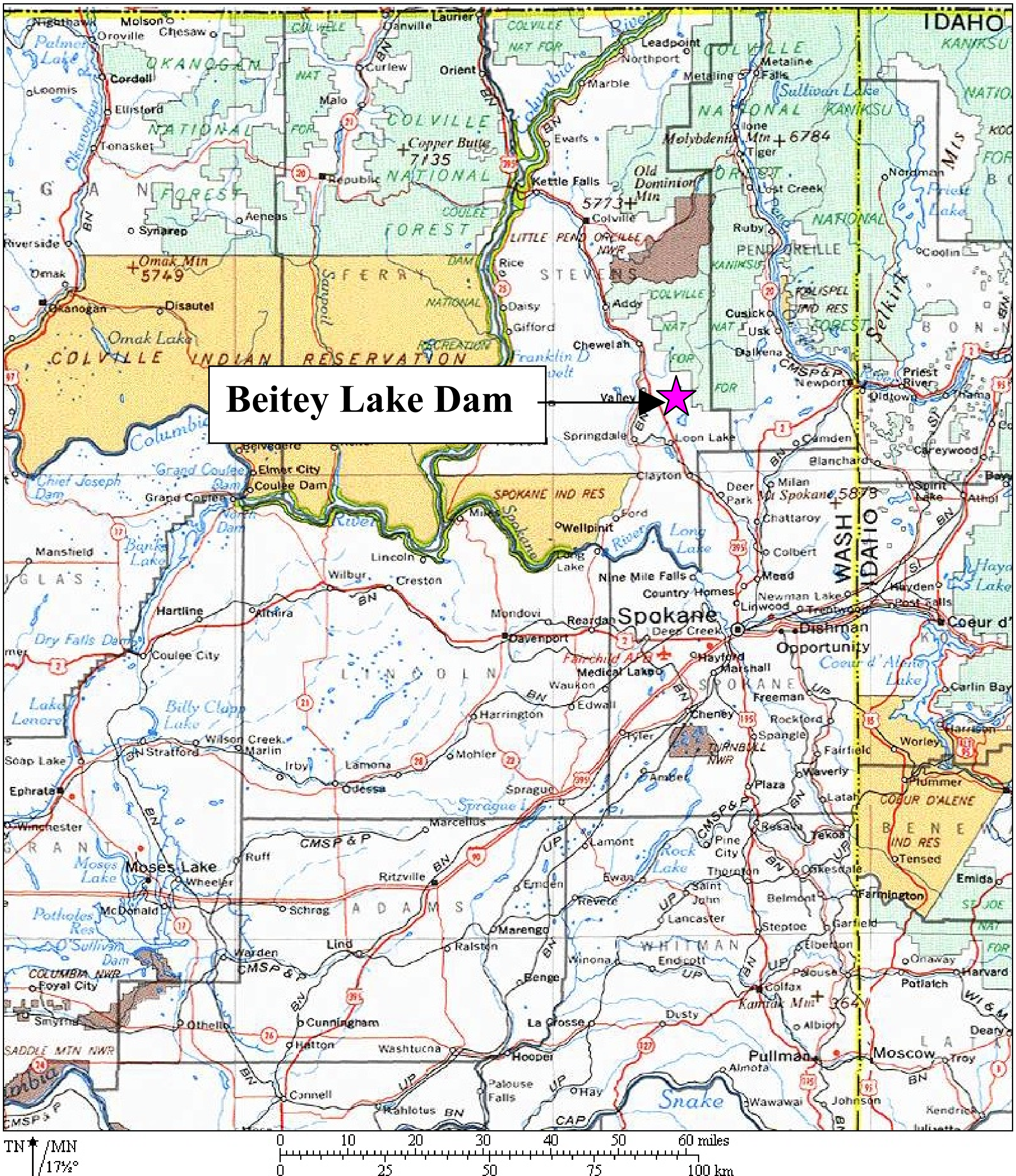

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Figure 1 – Location Map

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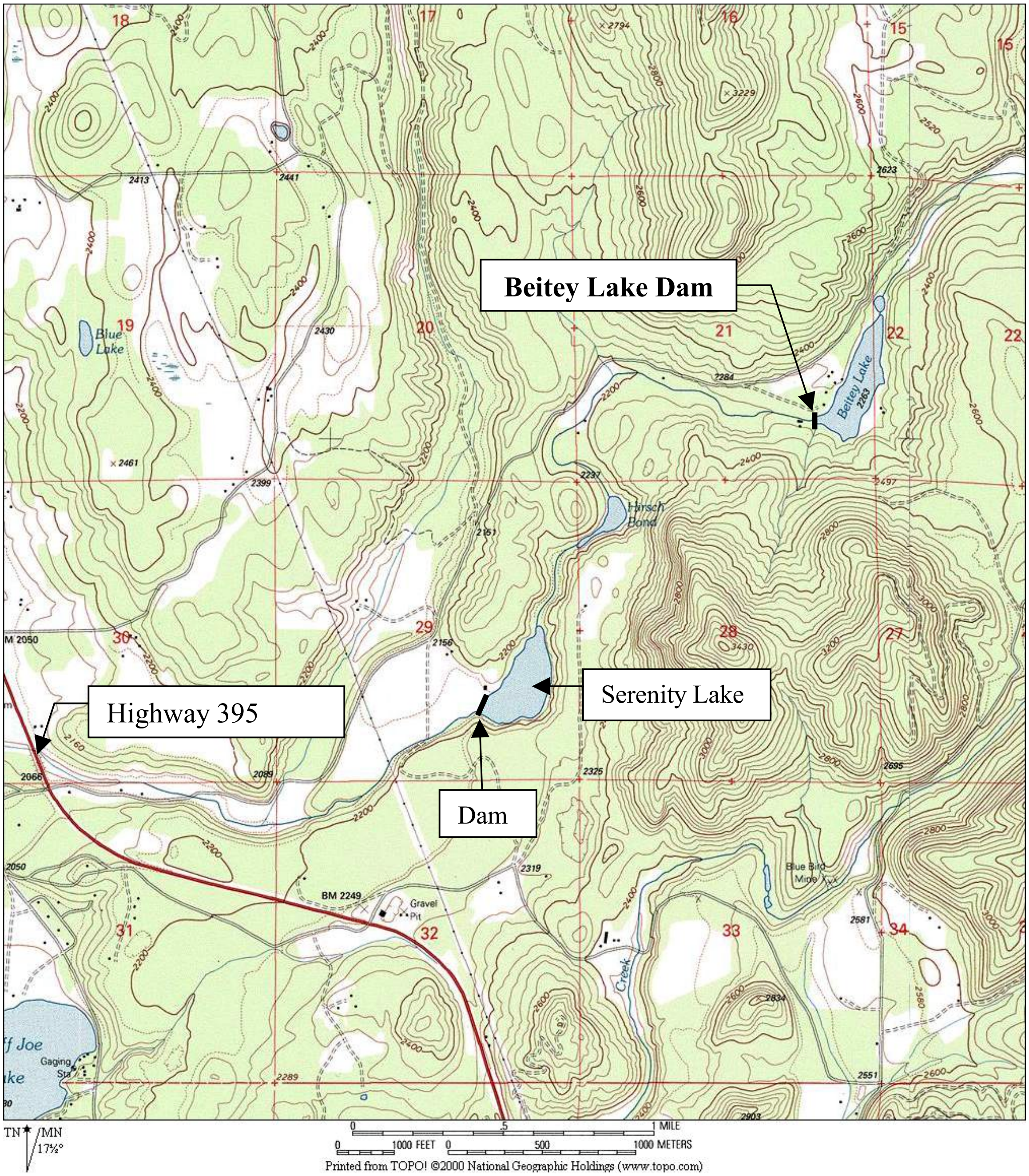

Figure 2 – Vicinity Map

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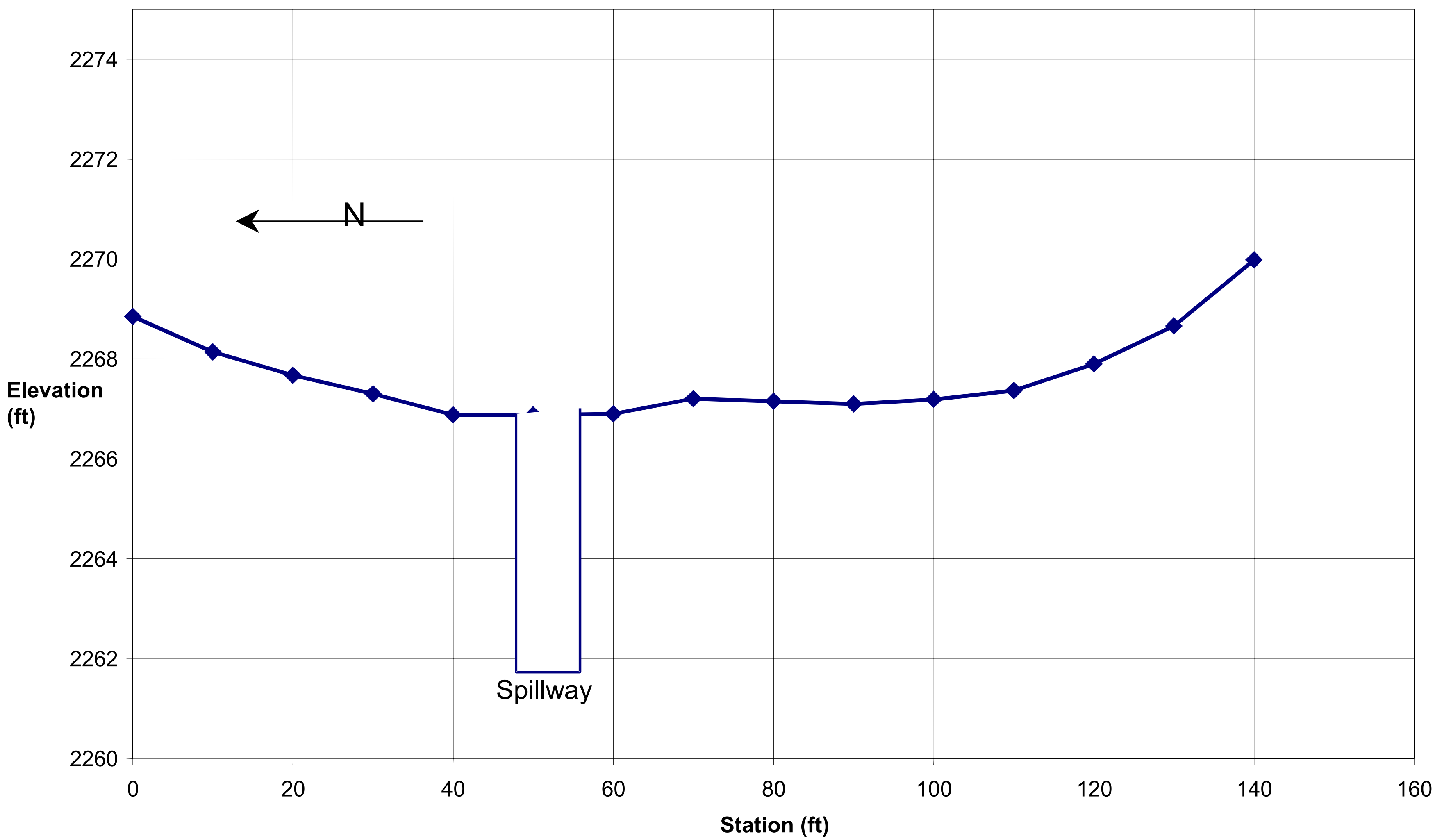
Figure 3 - Beitey Lake Dam Crest Profile



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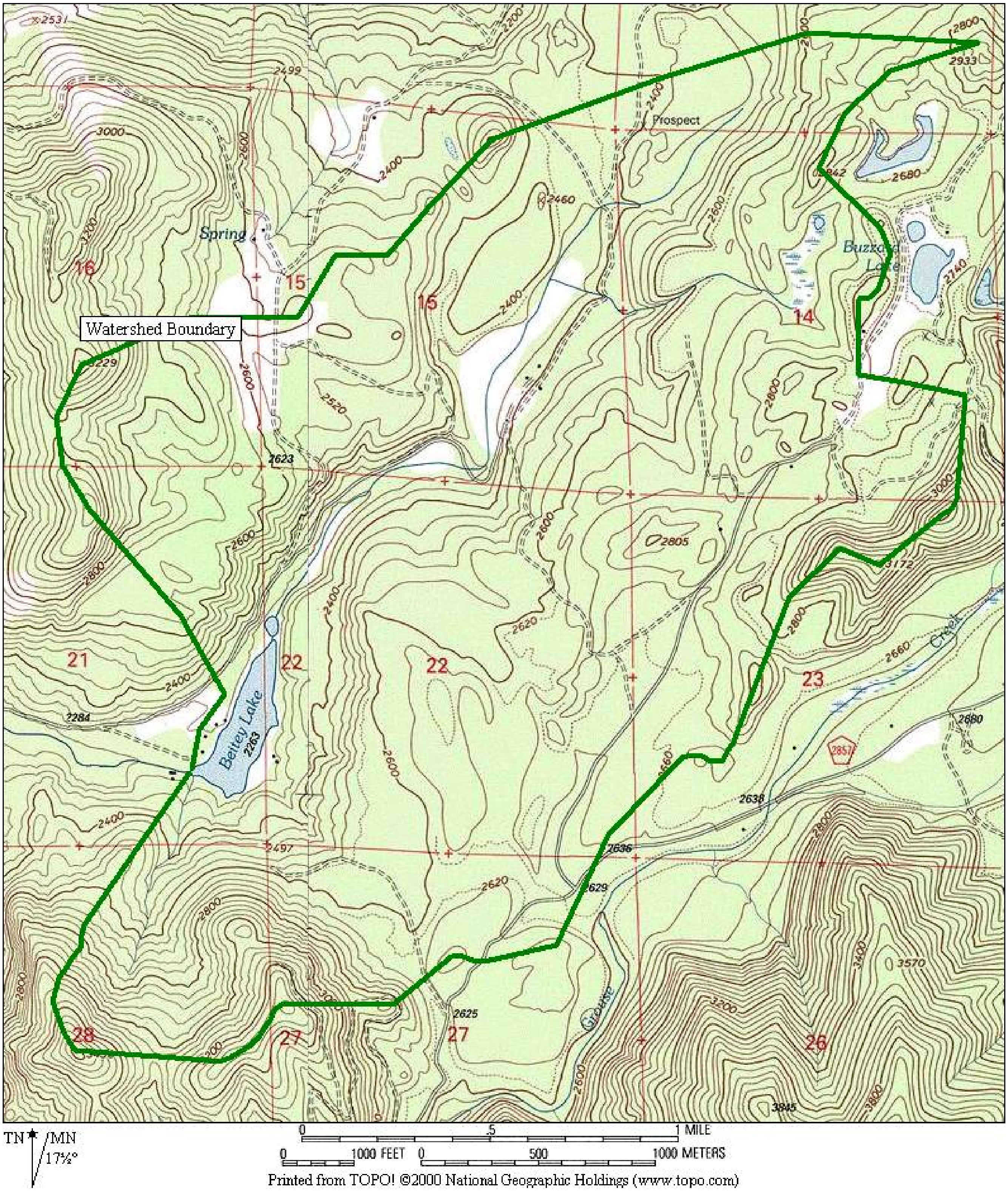

Figure 4 – Beitey Lake Watershed

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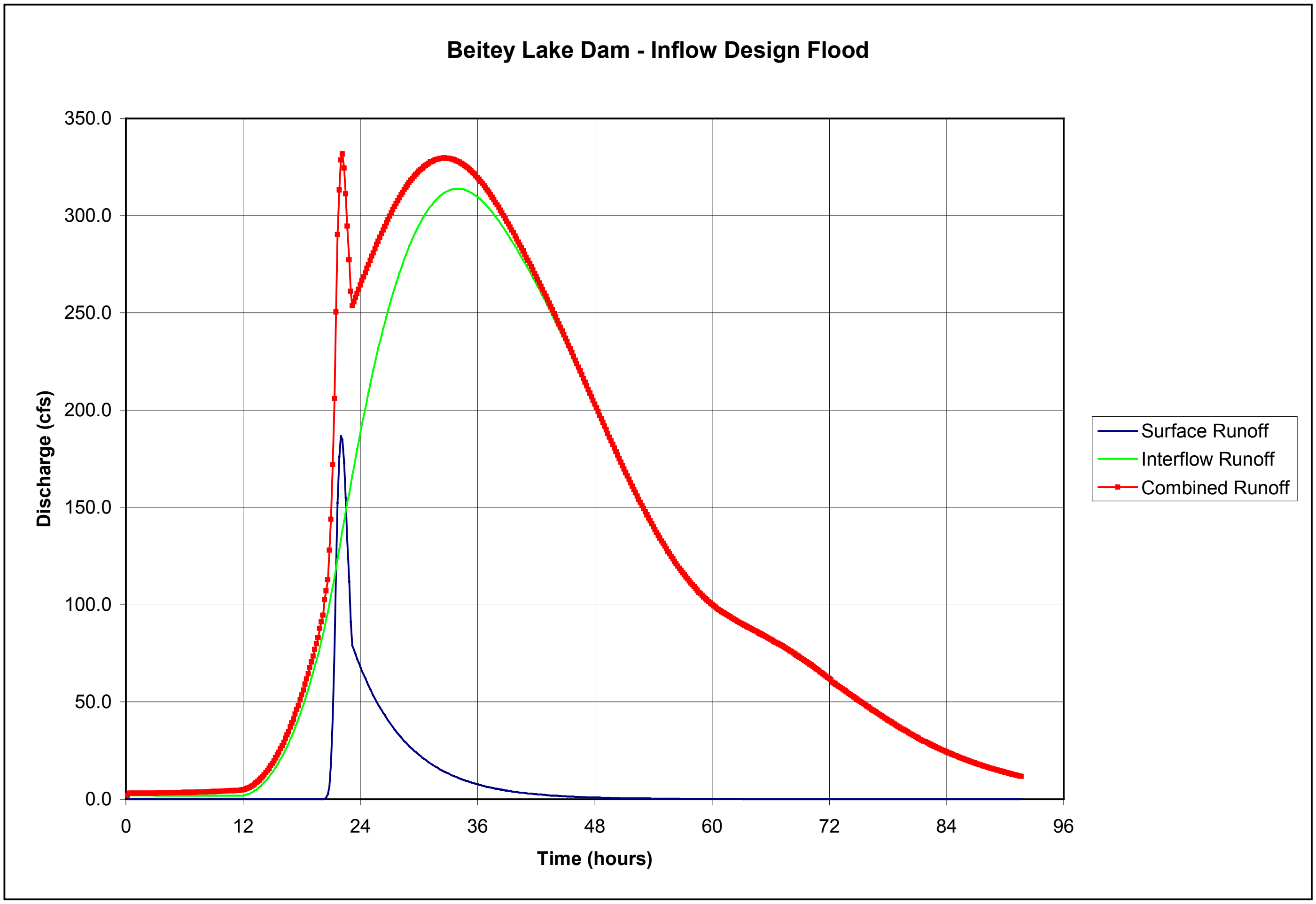

Figure 5 – Design Flood Hydrograph

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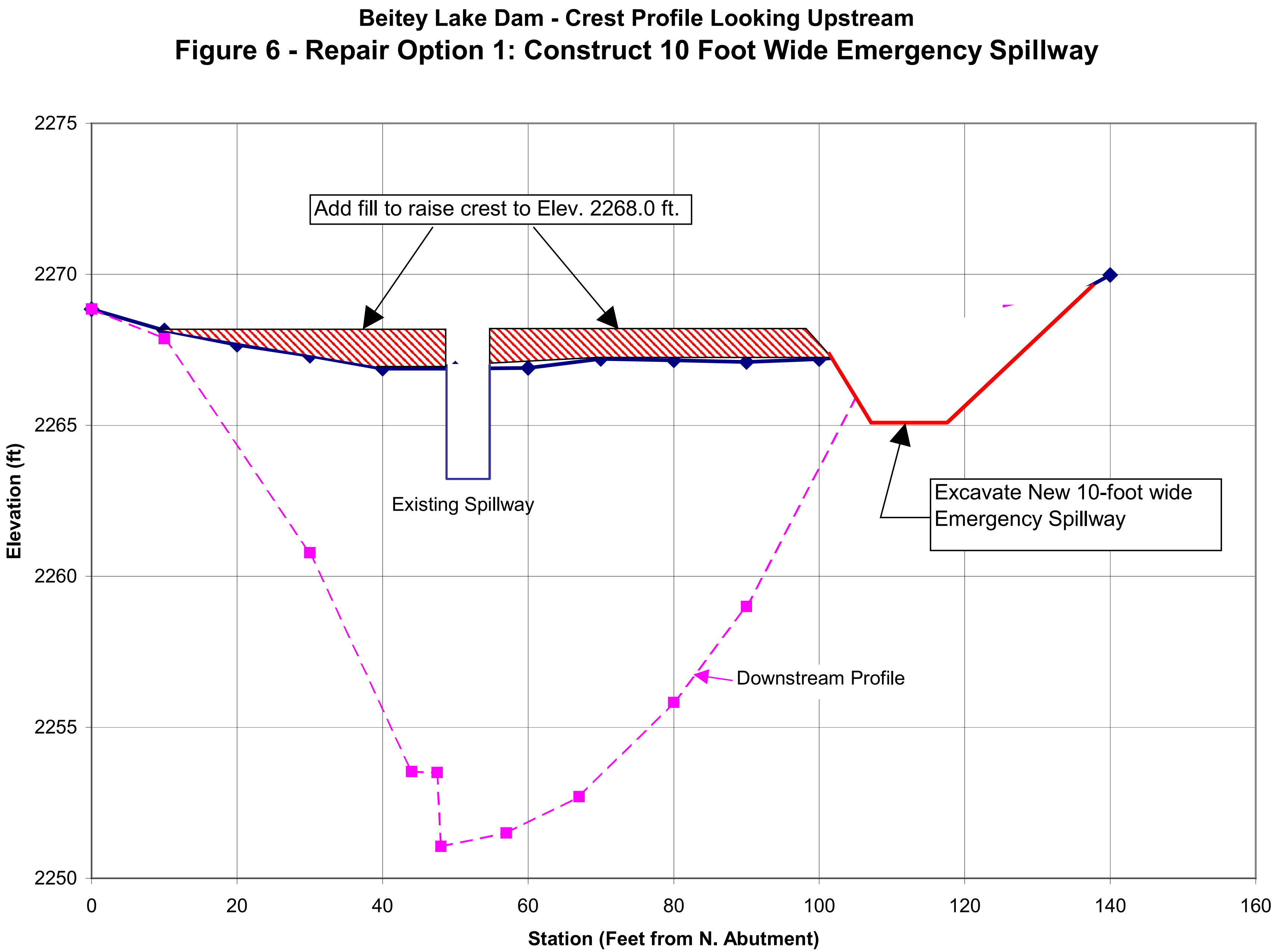
Beitey Lake Dam - Crest Profile Looking Upstream
Figure 6 - Repair Option 1: Construct 10 Foot Wide Emergency Spillway
Add fill to raise crest to Elev. 2268.0 ft.
Existing Spillway
Excavate New 10-foot wide Emergency Spillway
Downstream Profile
Elevation (ft)
Station (Feet from N. Abutment)
2275
2270
2265
2260
2255
2250
0
20
40
60
80
100
120
140
160

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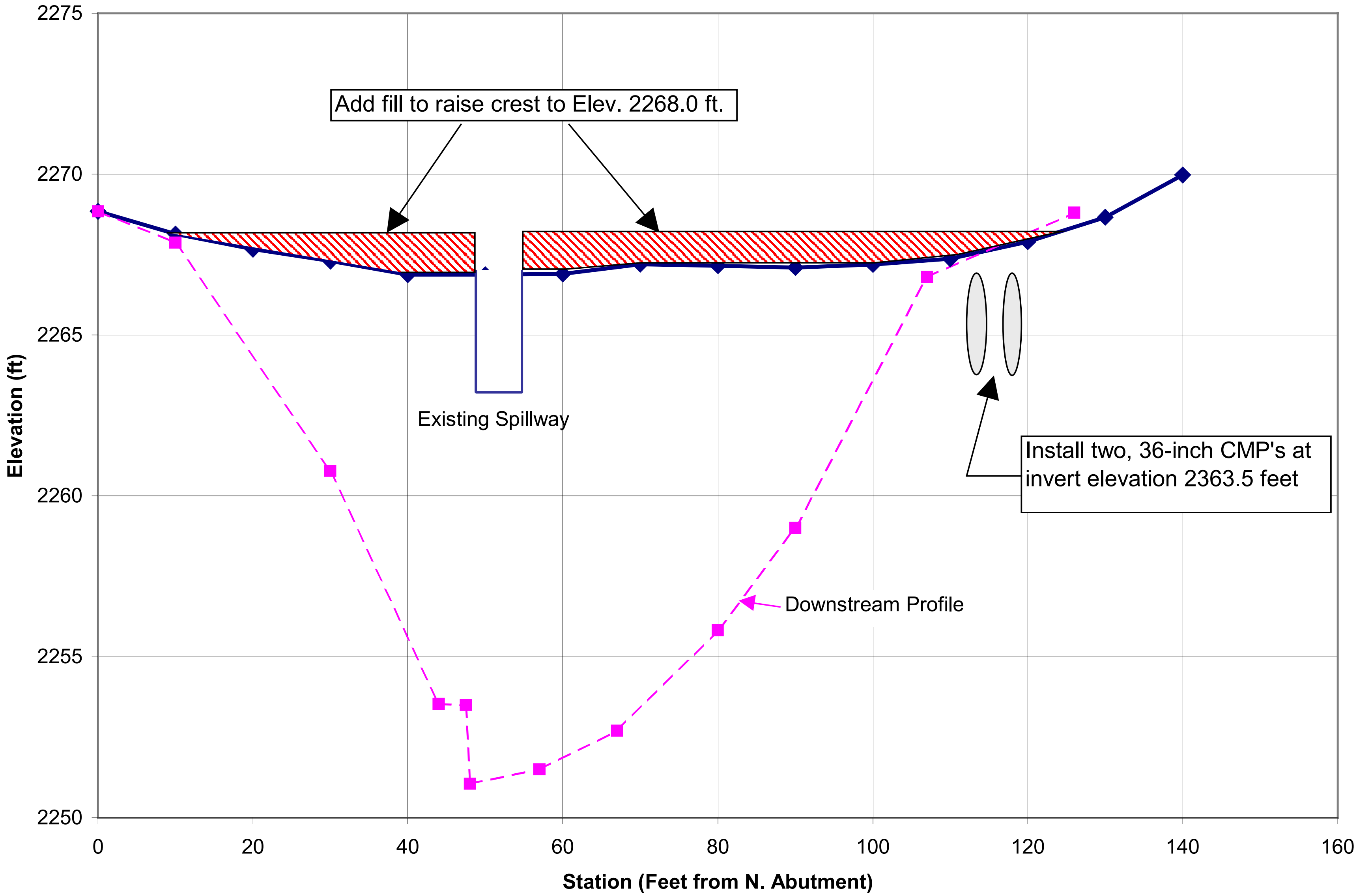
Beitey Lake Dam - Crest Profile Looking Upstream
Figure 7 - Repair Option 2: Install Twin 36-inch Pipes



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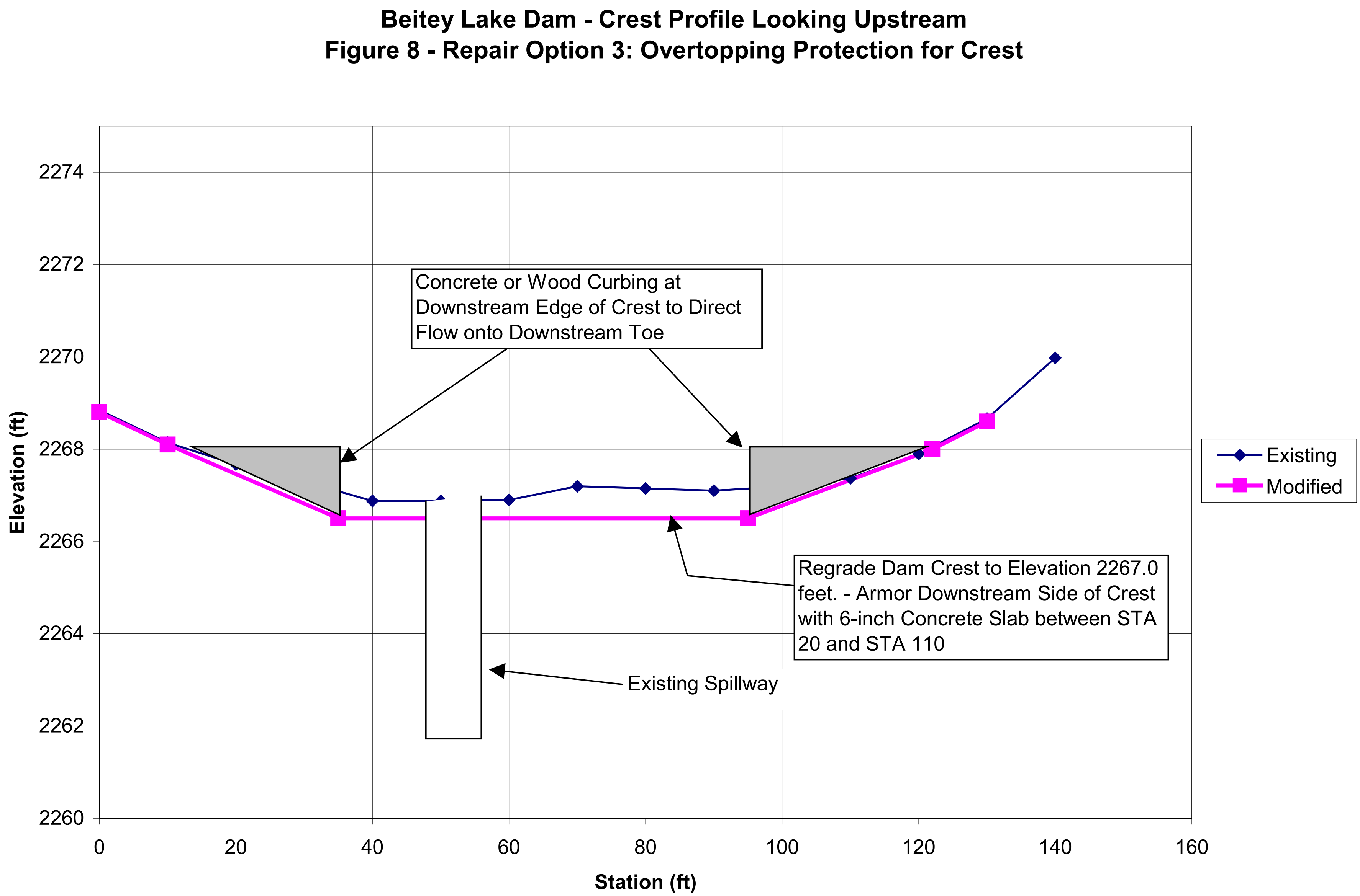
Beitey Lake Dam - Crest Profile Looking Upstream
Figure 8 - Repair Option 3: Overtopping Protection for Crest
Elevation (ft)
2274
2272
2270
2268
2266
2264
2262
2260
0
20
40
60
80
100
120
140
160
Station (ft)
Concrete or Wood Curbing at Downstream Edge of Crest to Direct Flow onto Downstream Toe
Regrade Dam Crest to Elevation 2267.0 feet. - Armor Downstream Side of Crest with 6-inch Concrete Slab between STA 20 and STA 110
Existing Spillway
Existing
Modified

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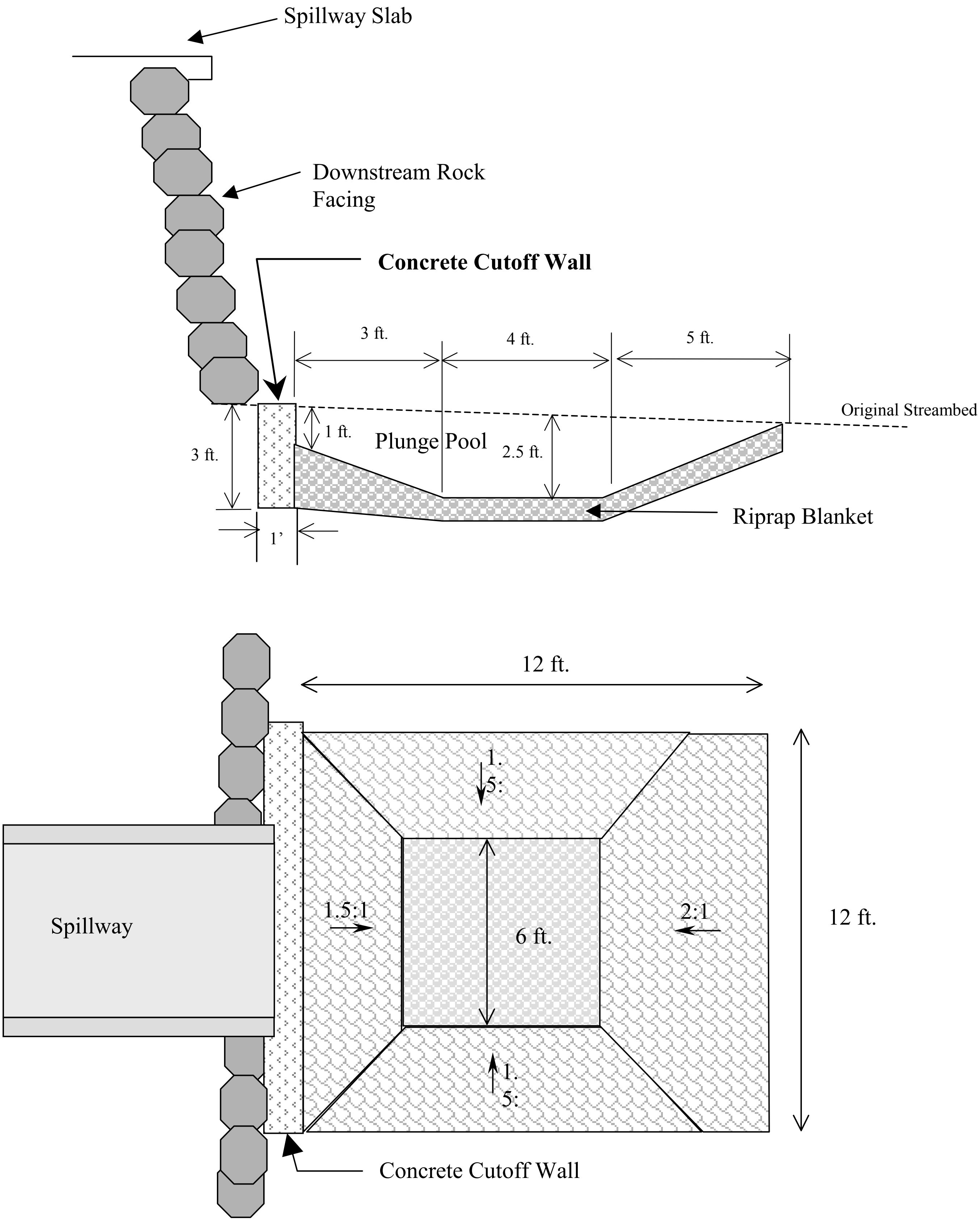
Figure 9 - Stilling Basin Conceptual Plan

Not to scale



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Appendix B - Photographs

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Photo 1: Beitey Lake Dam Downstream Face

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Photo 2: Crest & Downstream Face Looking South

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Photo 3: Upstream Face & Dam Crest Looking South

Photo 4: Downstream Face Looking North

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Appendix C – References

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